PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 29 January 2001 (29.01.01)	
International application No. PCT/GB00/02104	**Applicant's or agent's file reference** MJB06733WO
International filing date (day/month/year) 01 June 2000 (01.06.00)	**Priority date** (day/month/year) 01 June 1999 (01.06.99)
Applicant BRICE, James, Paul et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

18 December 2000 (18.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Olivia TEFY
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

The demand must be filed directly with the competent International Preliminary Examining Authority or, if two or more Authorities are competent, with the one chosen by the applicant. The name or two-letter code of that Authority may be indicated by the applicant on the line below:

IPEA/ _____

PCT

CHAPTER II

DEMAND

under Article 31 of the Patent Cooperation Treaty:
The undersigned requests that the international application specified below be the subject of international preliminary examination according to the Patent Cooperation Treaty and hereby elects all eligible States (except where otherwise indicated).

For International Preliminary Examining Authority use only

Identification of IPEA	Date of receipt of DEMAND

Box No. I IDENTIFICATION OF THE INTERNATIONAL APPLICATION

Applicant's or agent's file reference: MJB06733WO

International application No.	International filing date *(day/month/year)*	(Earliest) Priority date *(day/month/year)*
PCT/GB 00/02104	01 June 2000 (01.06.00)	01 June 1999 (01.06.99)

Title of invention
Improvements in Radio Positioning Systems

Box No. II APPLICANT(S)

Name and address:
Cambridge Positioning Systems Ltd
62-64 Hills Road
Cambridge
CB2 1LA
United Kingdom

Telephone No.:

Facsimile No.:

Teleprinter No.:

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

Name and address:
BRICE, James Paul
4 Brampton Road
Cambridge
CB1 3HL
United Kingdom

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

Name and address:
DUFFETT-SMITH, Peter James
41 Denmark Road
Cottenham
Cambridge
CB4 8QS
United Kingdom

State *(that is, country)* of nationality: GB

State *(that is, country)* of residence: GB

[X] Further applicants are indicated on a continuation sheet.

International application No.
PCT/GB 00/02104

Continuation of Box No. II APPLICANT(S)

If none of the following sub-boxes is used, this sheet is not to be included in the demand.

Name and address:

HANSEN, Paul
2 Providence Close
Somersha,
Cambridge
PE17 3YR
United Kingdom

State *(that is, country)* of nationality:	State *(that is, country)* of residence:
GB	GB

Name and address:

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address:

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

Name and address:

State *(that is, country)* of nationality:	State *(that is, country)* of residence:

☐ Further applicants are indicated on another continuation sheet.

International application No.
PCT/GB 00/02104

Box No. III AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The following person is [X] agent [ ] common representative

and [X] has been appointed earlier and represents the applicant(s) also for international preliminary examination.

[ ] is hereby appointed and any earlier appointment of (an) agent(s)/common representative is hereby revoked.

[ ] is hereby appointed, specifically for the procedure before the International Preliminary Examining Authority, in addition to the agent(s)/common representative appointed earlier.

Name and address:

Gill Jennings & Every
Broadgate House
7 Eldon Street
London
EC2M 7LH
United Kingdom

Telephone No.: +44 20 7377 1377

Facsimile No.: +44 20 7377 1310

Teleprinter No.:

[ ] **Address for correspondence**: Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

Box No.IV BASIS FOR INTERNATIONAL PRELIMINARY EXAMINATION

Statement concerning amendments:*

1. The applicant wishes the international preliminary examination to start on the basis of:

[X] the international application as originally filed

the description [ ] as originally filed
[ ] as amended under Article 34

the claims [ ] as originally filed
[ ] as amended under Article 19 (together with any accompanying statement)
[ ] as amended under Article 34

the drawings [ ] as originally filed
[ ] as amended under Article 34

2. [ ] The applicant wishes any amendment to the claims under Article 19 to be considered as reversed.

3. [ ] The applicant wishes the start of the international preliminary examination to be postponed until the expiration of 20 months from the priority date unless the International Preliminary Examining Authority receives a copy of any amendments made under Article 19 or a notice from the applicant that he does not wish to make such amendments (Rule 69.1(d)). *(This check-box may be marked only where the time limit under Article 19 has not yet expired.)*

* Where no check-box is marked, international preliminary examination will start on the basis of the international application as originally filed or, where a copy of amendments to the claims under Article 19 and/or amendments of the international application under Article 34 are received by the International Preliminary Examining Authority before it has begun to draw up a written opinion or the international preliminary examination report, as so amended.

Language for the purposes of international preliminary examination: ENGLISH

[X] which is the language in which the international application was filed.

[ ] which is the language of a translation furnished for the purposes of international search.

[ ] which is the language of publication of the international application.

[ ] which is the language of the translation (to be) furnished for the purposes of international preliminary examination.

Box No.V ELECTION OF STATES

The applicant hereby **elects all eligible States** *(that is, all States which have been designated and which are bound by Chapter II of the PCT)*

excluding the following States which the applicant wishes not to elect:

International application No.
PCT/GB 00/02104

Box No.VI CHECK LIST

The demand is accompanied by the following elements, in the language referred to in Box No. IV, for the purposes of international preliminary examination:

For International Preliminary Examining Authority use only

				received	not received
1.	translation of international application	:	sheets	☐	☐
2.	amendments under Article 34	:	sheets	☐	☐
3.	copy (or, where required, translation) of amendments under Article 19	:	sheets	☐	☐
4.	copy (or, where required, translation) of statement under Article 19	:	sheets	☐	☐
5.	letter	:	sheets	☐	☐
6.	other *(specify)*	:	sheets	☐	☐

The demand is also accompanied by the item(s) marked below:

1. ☐ fee calculation sheet
2. ☐ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ nucleotide and/or amino acid sequence listing in computer readable form
6. ☐ other *(specify)*:

Box No.VII SIGNATURE OF APPLICANT, AGENT OR COMMON REPRESENTATIVE

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the demand).

For the Applicant
Gill Jennings & Every

BRUNNER, Michael John

Date: 15 December 2000

For International Preliminary Examining Authority use only

1. Date of actual receipt of DEMAND:
2. Adjusted date of receipt of demand due to CORRECTIONS under Rule 60.1(b):
3. ☐ The date of receipt of the demand is AFTER the expiration of 19 months from the priority date and item 4 or 5, below, does not apply. ☐ The applicant has been informed accordingly.
4. ☐ The date of receipt of the demand is WITHIN the period of 19 months from the priority date as extended by virtue of Rule 80.5.
5. ☐ Although the date of receipt of the demand is after the expiration of 19 months from the priority date, the delay in arrival is EXCUSED pursuant to Rule 82.

For International Bureau use only

Demand received from IPEA on:

Payment of fees and costs

European Patent Office
Directorate Cash and Accounts
80298 Munchen
(+49-89) 2399-2528
Internet: www.european-patent-office.org

Please complete using a typewriter or a word processor

01 Name of payer: Gill Jennings & Every

02 Address: Broadgate House
7 Eldon Street
London EC2M 7LH UK.

Payer's reference: MJB06733WO 01/01/01

Mode of payment
- [ ] Bank/Giro transfer — Bank/Giro Office:
- [ ] Enclosed Cheque No.
- [X] Debit from deposit account with the EPO is requested — Deposit account No.: 2805.0014

Patent application / Patent No. (A separate form is required for each application)

03 EP: | PCT: PCT/GB 00/02104 | 03

	code		currency	Amount
04	001	Filing fee		
05	002	Search fee		
06	005	Designation fee(s)		
07	015	Claims fee(s) (Rule 31 (1) EPC)		
08	055	Additional copy		
09	006	Examination fee		
10	007	Fee for grant including fee for printing (up to 35 pages)		
11	008	Additional fee for printing (more than 35 pages)		
12	033	Renewal fee for the 3rd year		
13	034	Renewal fee for the 4th year		
14	035	Renewal fee for the 5th year		
15		Extension fee(s) for :		
16	021	Int'l Preliminary Exam Fee	€	1533.00
17	224	PCT Handling Fee (EP)	€	147.00
18				
19				
20				
21				
22		Total	€	1680.00

Signature

Place, Date: London 15/12/00

H:\forms\wp8forms\epo1010

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

PCT

To:

GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH
GRANDE BRETAGNE

NOTIFICATION OF RECEIPT OF DEMAND BY COMPETENT INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

(PCT Rules 59.3(e) and 61.1(b), first sentence and Administrative Instructions, Section 601(a))

Date of mailing *(day/month/year)*	16. 01. 01
Applicant's or agent's file reference: MJB06733WO	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB 00/02104	01/06/2000	01/06/1999

Applicant

CAMBRIDGE POSITIONING SYSTEMS Ltd

1. The applicant is hereby **notified** that this International Preliminary Examining Authority considers the following date as the date of receipt of the demand for international preliminary examination of the international application:

18/12/2000

2. This date of receipt is:

- [x] the actual date of receipt of the demand by this Authority (Rule 61.1(b)).
- [ ] the actual date of receipt of the demand on behalf of this Authority (Rule 59.3(e)).
- [ ] the date on which this Authority has, in response to the invitation to correct defects in the demand (Form PCT/IPEA/404), received the required corrections.

3. [ ] **ATTENTION:** That date of receipt is **AFTER** the expiration of 19 months from the priority date. Consequently, the election(s) made in the demand does (do) not have the effect of postponing the entry into the national phase until 30 months from the priority date (or later in some Offices) (Article 39(1)). Therefore, the acts for entry into the national phase must be performed within 20 months from the priority date (or later in some Offices) (Article 22). For details, see the *PCT Applicant's Guide*, Volume II.

[ ] *(If applicable)* This notification confirms the information given by telephone, facsimile transmission or in person on:

_____

4. Only where paragraph 3 applies, a copy of this notification has been sent to the International Bureau.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. (+49-89) 2399-0, Tx: 523656 epmu d Fax: (+49-89) 2399-4465	KENNEDY M B Tel. (+49-89) 2399-2976

EUROPÄISCHES PATENTAMT · EUROPEAN PATENT OFFICE · OFFICE EUROPÉEN DES BREVETS

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

DIARIED

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
GILL JENNINGS & EVERY
Broadgate House
7 Eldon Street
London EC2M 7LH
UNITED KINGDOM

	Date of mailing *(day/month/year)* 12/09/2000
Applicant's or agent's file reference MJB06733WO	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/GB 00/ 02104	International filing date *(day/month/year)* 01/06/2000
Applicant CAMBRIDGE POSITIONING SYSTEMS Ltd	

1. [X] The applicant is hereby notified that the International Search Report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the International Search Report; however, for more details, see the notes on the accompanying sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Fascimile No.: (41–22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. [ ] The applicant is hereby notified that no International Search Report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. [ ] **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

[ ] the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

[ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau as provided in Rules 90*bis*.1 and 90*bis*.3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the International Searching Authority	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL–2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Eric Walsh

Form PCT/ISA/220 (July 1998)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under article 19. The Notes are based on the requirements of the Patent Cooperation Treaty, the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule", and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended?

Under Article 19, only the claims may be amended.

During the international phase, the claims may also be amended (or further amended) under Article 34 before the International Preliminary Examining Authority. The description and drawings may only be amended under Article 34 before the International Examining Authority.

Upon entry into the national phase, all parts of the international application may be amended under Article 28 or, where applicable, Article 41.

When? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

The amendments must be made in the language in which the international application is to be published.

What documents must/may accompany the amendments?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confused with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must be in English or French, at the choice of the applicant. However, if the language of the international application is English, the letter must be in English; if the language of the international application is French, the letter must be in French.

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped),whether

(i) the claim is unchanged;

(ii) the claim is cancelled;

(iii) the claim is new;

(iv) the claim replaces one or more claims as filed;

(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."

2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."

3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."

4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

It must be in the language in which the international appplication is to be published.

It must be brief, not exceeding 500 words if in English or if translated into English.

It should not be confused with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It may not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

Consequence if a demand for international preliminary examination has already been filed

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
MJB06733WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/ 02104	01/06/2000	01/06/1999
Applicant		
CAMBRIDGE POSITIONING SYSTEMS Ltd		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language,** the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

   [ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

   [ ] contained in the international application in written form.

   [ ] filed together with the international application in computer readable form.

   [ ] furnished subsequently to this Authority in written form.

   [ ] furnished subsequently to this Authority in computer readble form.

   [ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   [ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

   [X] the text is approved as submitted by the applicant.

   [ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

   [X] as suggested by the applicant.

   [ ] because the applicant failed to suggest a figure.

   [ ] because this figure better characterizes the invention.

   [ ] None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No
GB 00/02104

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S5/10 G01S5/00 G01S1/02 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 689 270 A (GREENBAUM LOUIS A ET AL) 18 November 1997 (1997-11-18)	1,8
Y	abstract	2-6, 9-13,15
A	column 2, line 5 -column 3, line 32 column 5, line 60 -column 6, line 16 column 15, line 37 -column 16, line 57 column 17, line 9 -column 18, line 8 column 19, line 12 -column 20, line 17 figure 1	7,14

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2000	12/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roost, J

2

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 11384 A (CAMBRIDGE POSITIONING SYS LTD ;GRAINGE KEITH J B (GB); DUFFETTT SM) 27 March 1997 (1997-03-27) cited in the application	2-6, 9-13,15
A	abstract page 2, line 28 -page 3, line 31 page 4, line 21 -page 5, line 14 page 17, line 20 -page 18, line 4	1,8
X	WO 98 52376 A (NOKIA TELECOMMUNICATIONS OY ;RANTALAINEN TIMO (FI); SILVENTOINEN M) 19 November 1998 (1998-11-19)	1,8
A	abstract page 1, line 23 - line 34 page 4, line 16 -page 6, line 11 page 7, line 24 -page 10, line 17 page 11, line 35 -page 12, line 13 page 13, line 1 - line 12	2-4,6,7, 9-11, 13-15
A	WO 97 23785 A (DRANE CHRISTOPHER R ;MACNAUGHTAN MALCOLM D (AU); SCOTT CRAIG A (AU) 3 July 1997 (1997-07-03) abstract page 6, line 12 - line 15 page 10, line 4 -page 14, line 14	1,2,8,9
A	WO 97 30360 A (ERICSSON TELEFON AB L M) 21 August 1997 (1997-08-21) abstract page 6, line 17 -page 7, line 5 page 11, line 23 -page 14, line 31	1,2,8,9
A	WO 99 21028 A (CAMBRIDGE POSITIONING SYS LTD ;DUFFETT SMITH PETER (GB); HANSEN PA) 29 April 1999 (1999-04-29) cited in the application abstract page 1, line 18 -page 2, line 7 page 8, line 15 - line 28 page 10, line 12 -page 12, line 15	1,2
A	EP 0 303 371 A (DUFFETT SMITH PETER JAMES) 15 February 1989 (1989-02-15) cited in the application abstract	2

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
GB 00/02104

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5689270 A	18-11-1997	US 5499032 A	12-03-1996
		US 5280295 A	18-01-1994
		US 5173710 A	22-12-1992
		CA 2179169 A	22-06-1995
		AU 665571 B	11-01-1996
		AU 2540292 A	16-03-1993
		CA 2114648 A	04-03-1993
		EP 0598844 A	01-06-1994
		JP 6510120 T	10-11-1994
		WO 9304378 A	04-03-1993
WO 9711384 A	27-03-1997	AU 713289 B	25-11-1999
		AU 6994296 A	09-04-1997
		BR 9610493 A	06-04-1999
		CA 2230982 A	27-03-1997
		CN 1202968 A	23-12-1998
		EP 0880712 A	02-12-1998
		JP 11513482 T	16-11-1999
		RU 2137150 C	10-09-1999
		US 6094168 A	25-07-2000
WO 9852376 A	19-11-1998	AU 2895997 A	08-12-1998
		EP 1008269 A	14-06-2000
		NO 995452 A	08-11-1999
WO 9723785 A	03-07-1997	AU 708505 B	05-08-1999
		AU 1133297 A	17-07-1997
WO 9730360 A	21-08-1997	SE 513196 C	31-07-2000
		AU 1817497 A	02-09-1997
		CA 2245878 A	21-08-1997
		CN 1211377 A	17-03-1999
		EP 0883968 A	16-12-1998
		JP 2000504838 T	18-04-2000
		SE 9600577 A	17-08-1997
		US 5960355 A	28-09-1999
WO 9921028 A	29-04-1999	AU 9549898 A	10-05-1999
		EP 1025453 A	09-08-2000
		NO 20002068 A	19-04-2000
EP 0303371 A	15-02-1989	AT 86757 T	15-03-1993
		AU 2120788 A	09-03-1989
		BR 8807655 A	05-06-1990
		CA 1314964 A	23-03-1993
		DE 3879032 A	15-04-1993
		DE 3879032 T	24-06-1993
		DK 34690 A	09-02-1990
		EP 0377592 A	18-07-1990
		ES 2038758 T	01-08-1993
		WO 8901637 A	23-02-1989
		HK 38994 A	29-04-1994
		JP 2504673 T	27-12-1990
		NO 177944 B	11-09-1995
		US 5045861 A	03-09-1991

09183044457 (27C1/francoma) 6/1/99 14

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
MJB06733WO		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/GB00/02104	01/06/2000	01/06/1999
International Patent Classification (IPC) or national classification and IPC G01S5/10		
Applicant CAMBRIDGE POSITIONING SYSTEMS Ltd		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 7 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
18/12/2000	24.08.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer McLean, G Telephone No. +49 89 2399 2608

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB00/02104

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:
Description, pages:

1-5,9-15	as originally filed			
6-8,8A	as received on	16/05/2001	with letter of	15/05/2001

Claims, No.:

1-8,9 (part)	as received on	16/05/2001	with letter of	15/05/2001
9 (part),10-15	as received on	18/05/2001	with letter of	16/05/2001

Drawings, sheets:

1-9	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	4-7,11-15
	No:	Claims	1-3, 8-10
Inventive step (IS)	Yes:	Claims	
	No:	Claims	4-7, 11-15
Industrial applicability (IA)	Yes:	Claims	1-15
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

Item V

The following documents are introduced:-
D1= WO-A-97/23785:
D3= WO-A-99/21028; as acknowledged in the application, whole document.

Novelty

Claims 1-3 and 8-10 relate to the determination of a list of offsets (effectively of any kind) relative to a common reference, which may be used in a radio positioning system or method. The list is realised by combining the information from two or more receivers. All of this is disclosed in D1. It is made clear in D1 at page 4 lines 20-23, especially line 21 that data may be acquired from "several" (e.g. two or more) receivers. It is also pointed out in D1 (page 12 lines 10-13) that system wide synchronisation may be achieved provided there is overlap between the transmission source signals (the base stations of D1). System wide synchronisation is considered to be none other than the list of the present invention in the case when all transmssion sources of a system might be embraced by the list. It is considered to be inherent in D1, from the very use made of the offsets, that they must be in effect listed in the precise manner required by the aforesaid claims, which lack novelty accordingly with respect to D1.

Inventive Step

The remaining claims 4-7 and 11 to 15 merely make use of the offset information in positioning, in a manner known in the art, in particular from D3. These claims lack inventive step accordingly.

Even at the level of the disclosure, the present application differs from D3 merely in compiling at a location designated a "virtual location measurement unit" of the offset data for all of the transmitters in the system, a matter without the slightest technical or inventive significance when compared with the disclosure in D3.

It is further noted that the choice of the terminology "virtual location measurement unit" is considered to be purely conventional, the latter being no more than a notional receiver which might be reachable by all transmitters in the system, leading to a list more comprehensive list than that achievable by any one receiver, in the application just as in D1. It is noted too that the claims are silent as to any "virtual offsets at a location which is not a location measuring unit". Indeed, the

offsets in the application and in the prior art are attributes of the transmission sources themselves.

Item VII

Should the application enter the regional phase in spite of the above, the following matters will need attention:-

(i) those independent claims which are retained should be cast in correct two-part form (Rule 6.3(b)) with respect to that one of D1 or D3 which comes nearest to the claimed subject matter.

(ii) reference signs in parentheses should be inserted in the claims [Rule 6.2(b)]. This applies to both the preamble and characterising portion.

(iii) the opening pages of the description should be brought into line with the new claims [Rule 5.1(a)(iii)].

(iv) document D1 should be referred to in appropriate terms in the description to comply with Rule 5.1(a)(ii).

(v) the suggestions throughout the description to the effect that copending documents are "incorporated by reference" obscures the precise teaching of the present application and need to be deleted.

Item VIII

The claims are not concise (Article 6 PCT). There is considered to be no reason to offer more than a single independent claim in each category in this case. The independent claims are particularly speculative in suggesting that the receiver positions merely "may" be known. The determination of the offsets which are merely "combined", appears categorically to require knowledge of the receiver positions.

****

The present invention teaches how the same advantages of an (effectively) synchronised LMU network may be obtained by setting up one or more 'virtual LMUs' in the network which act as interface nodes for the real LMUs.

According to a first aspect of the invention, there is provided a method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the method comprising

(a) acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) combining the acquired data and calculating the list of offsets corresponding to the given location relative to the common reference.

In practice the offsets from the list can be used in place of offsets obtained directly from the receiver or receivers.

The relative offsets in time, phase, frequency, or derivatives thereof, with respect to each other or with respect to a reference source, of the signals received by a first receiver from a plurality of the transmission sources may be represented by corresponding offsets or differences in the distances between the transmission sources and the first or second receivers.

The invention also includes apparatus using the method above, the apparatus comprising

(a) means for acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) means for combining the acquired data and calculating the list of offsets corresponding to the given location relative to the common reference.

In a method using techniques similar to or as described in EP-A-0 880 712, in place of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, data representative of the received signals may be used, from which the offsets of signals received from the transmission sources relative to the reference source may be determined.

Therefore, the invention also includes a method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the method comprising

(a) acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) combining the offsets so determined and calculating the list of offsets corresponding to the given location relative to the common reference.

The invention also includes apparatus for carrying out the method described immediately above, the apparatus comprising

(a) means for acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) means for determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) means for combining the offsets so determined and calculating the list of offsets corresponding to the given location relative to the common reference.

A radio positioning method and system including either of the methods and apparatus defined above also form part of the present invention.

The invention also includes apparatus (a 'virtual LMU') for carrying out either or both of these methods. The apparatus may include a computer (located anywhere convenient) and programmed to carry out the required process. Although the following description of a particular application of the invention concerns signals in a digital telephone network, it will be apparent that the invention is by no means restricted to this application but may be applied to any network of one or more transmitters, synchronised or unsynchronised, set up for any purpose.

A virtual LMU includes a computer process which may run on any computer platform able to obtain data from real LMUs. Accordingly, a further aspect of the invention includes a method of calculating and maintaining a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference.

It is assumed that the network of BTSs is *unsynchronised* in that the transmission time offsets of the BTS signals bear no constant or known relationship to each other, but that nevertheless the BTS oscillators are quite *stable*, so that their instantaneous frequencies change only slowly with time. In these circumstances, it is possible to predict the currently received offset in time, phase, frequency, or derivatives thereof of the signals from a given BTS by a given real LMU from sufficiently-recent historical data. The real LMUs in the network make measurements of all the BTSs they can detect in a cyclic fashion, repeating the cycle every few seconds. They maintain these measurements in a stack, replacing the oldest measurements with the most recent. A linear or low-order polynomial fit to the measurements therefore provides a predictor for extrapolation into the near future, or for interpolation in the recent past. Assume that the BTS oscillators are sufficiently stable that reliable predictions can be made

over a period of, say, ten minutes. Then, every few minutes, the virtual LMU (VLMU) contacts each real LMU and receives its predictors for the received offsets of the signals from all the BTSs in its measurement set. It is likely that many of the

CLAIMS

1. A method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the method comprising

(a) acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) combining the acquired data and calculating the list of offsets corresponding to the given location relative to the common reference.

2. A method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the method comprising

(a) acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) combining the offsets so determined and calculating the list of offsets corresponding to the given location relative to the common reference.

3. A radio positioning method for determining the position of one or more receivers the positions of which are unknown, which method includes the method of claim 1 or claim 2.

4. A radio positioning method according to claim 3, wherein the common reference comprises an external reference.

5. A radio positioning method according to claim 4, wherein the common reference comprises a GPS signal.

6. A radio positioning method according to any of claims 3 to 5, wherein the step of acquiring data from said one or more receivers includes instigating acquisition of said data from a common location.

7. A radio positioning method according to any of claims 3 to 5, wherein the step of acquiring data from said two or more receivers includes instigating acquisition of said data from each said receiver at times determined by each said receiver.

8. Apparatus for generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the apparatus comprising

(a) means for acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) means for combining the acquired data and calculating the list of offsets corresponding to the given location relative to the common reference.

9. Apparatus for generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, corresponding to a given location, relative to a common reference, the apparatus comprising

(a) means for acquiring data from two or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) means for determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) means for combining the offsets so determined and calculating the list of offsets corresponding to the given location relative to the common reference.

10. A radio positioning system including apparatus according to claim 8 or to claim 9.

11. A radio positioning system according to claim 10, wherein the common reference comprises a reference external to said receivers.

12. A radio positioning system according to claim 11, wherein the common reference comprises a GPS signal.

13. A radio positioning system according to any of claims 10 to 12, wherein the means for acquiring data from said two or more receivers includes a computer system arranged to instigate the transfer of said data from said two or more receivers to said computer system at times determined by said computer system.

14. A radio positioning system according to any of claims 10 to 13, wherein the means for acquiring data from said two or more receivers includes a computer system, and including means for instigating said acquisition of data from each said receiver at times determined by each said receiver.

15. A digital telephone network, including a radio positioning system according to any of claims 10 to 14.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 December 2000 (07.12.2000)

PCT

(10) International Publication Number
WO 00/73813 A1

(51) International Patent Classification[7]: G01S 5/10, 5/00, 1/02, H04Q 7/38

(21) International Application Number: PCT/GB00/02104

(22) International Filing Date: 1 June 2000 (01.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9912724.3 1 June 1999 (01.06.1999) GB

(71) Applicant *(for all designated States except US)*: CAMBRIDGE POSITIONING SYSTEMS LTD. [GB/GB]; 62-64 Hills Road, Cambridge CB2 1LA (GB).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: BRICE, James, Paul [GB/GB]; 4 Brampton Road, Cambridge CB1 3HL (GB). DUFFETT-SMITH, Peter, James [GB/GB]; 41 Denmark Road, Cottenham, Cambridge CB4 8QS (GB). HANSEN, Paul [GB/GB]; 2 Providence Close, Somersham, Cambridge PE17 3YR (GB).

(74) Agent: GILL JENNINGS & EVERY; Broadgate House, 7 Eldon Street, London EC2M 7LH (GB).

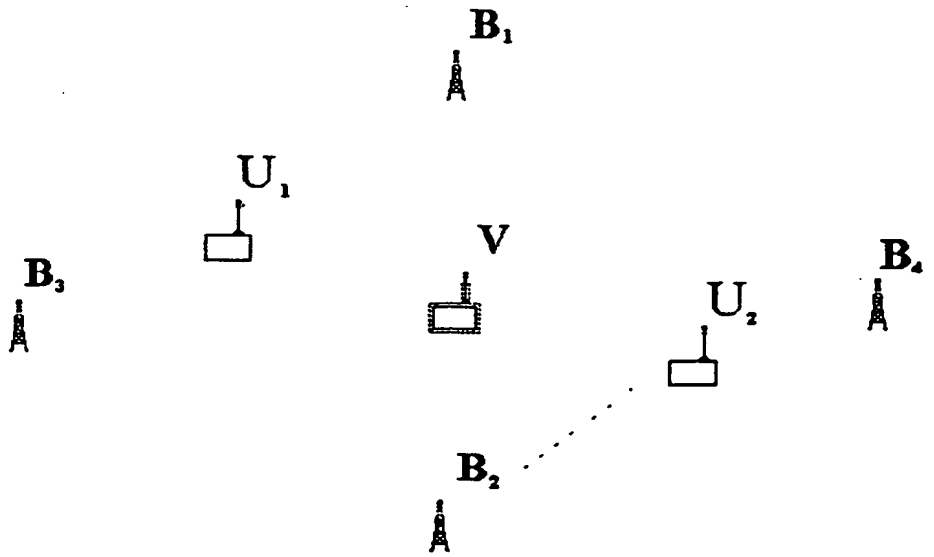
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *With international search report.*

[Continued on next page]

(54) Title: IMPROVEMENTS IN RADIO POSITIONING SYSTEMS



(57) Abstract: The invention described relates to a radio positioning system primarily for a mobile telephone network, in which a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference are generated. Data is acquired from one or more receivers, the positions of which may be known or determined. Such data are offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other. The acquired data is combined for calculating the list of offsets relative to the common reference.

WO 00/73813 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

IMPROVEMENTS IN RADIO POSITIONING SYSTEMS

The present invention relates generally to improvements in radio positioning systems and their methods of operation and, more particularly, to methods and apparatus for simplifying the acquisition of data required in such systems.

EP-A-0 303 371, the contents of which are hereby incorporated by reference, describes a radio navigation and tracking system which makes use of independent radio transmitters set up for other purposes. The signals from each transmitter, taken individually, are received by two receiving stations, one at a fixed and known location, and the other mounted on the mobile object whose position is to be determined. A representation of the signals received at one receiving station is sent via a link to a processor at the other receiving station, where the received signals are compared to find their phase differences or time delays. Three such measurements, made on three widely spaced independent transmitters, are sufficient to determine the position of the mobile receiver in two dimensions, i.e. its position on the ground. The phase or time offset between the master oscillators in the two receivers is also determined.

"CURSOR", as the system described in EP-A-0 303 371 is known, is a radio positioning system which can use the signals radiated by existing non-synchronised radio transmitters to locate the position of a portable receiver. Unlike some other systems which use the temporal coherence properties of networks of purpose-built synchronised transmitters, CURSOR makes use of the spatial coherence of the signals transmitted by single transmitters. In a further development (see EP-A-0 880 712 & WO-A-99/21028), the technology has been applied to find the position of a mobile phone handset in a GSM or other digital telephone system, and these are examples of an 'Enhanced Observed Time Difference' (E-OTD) method using the down-link signals radiated by the network of Base Transceiver Stations (BTS) of the telephone system.

In the digital mobile telephone application described in EP-A-0 880 712, the contents of which are hereby incorporated by reference, the signals from each BTS within range of the handset are received both by the handset itself and by a fixed nearby receiver, the Location Measurement Unit (LMU), whose position is accurately known.

Representations of the received signals are passed to a Mobile Location Centre (MLC) where they are compared in order to find the time difference between them. Figure 1 shows the geometry of a standard two-dimensional system. The origin of Cartesian co-ordinates x and y is centred on the LMU positioned at O. The orientation of the axes is immaterial, but may conveniently be set so that the y axis lies along the north-south local map grid. The handset, R, is at vector position **r** with respect to the LMU position O. A BTS, A, is shown at vector position **a**.

Consider first the signals from BTS A. The time difference, Δt_a, measured between the signals received at R and O is given by

$$\Delta t_a = (|\mathbf{r} - \mathbf{a}| - |\mathbf{a}|)/\upsilon + \varepsilon ,$$

where υ is the speed of the radio waves, ε is the clock time offset between the clocks in the receivers at R and O, and the vertical bars each side of vector quantities denote that it is the magnitude of the vectors which are used in the equation. The value of ε represents the synchronisation error between the measurements made by the two receivers. Similarly, may be written for two other BTSs (B and C) at vector positions **b** and **c** (not shown):

$$\Delta t_b = (|\mathbf{r} - \mathbf{b}| - |\mathbf{b}|)/\upsilon + \varepsilon ,$$

$$\Delta t_c = (|\mathbf{r} - \mathbf{c}| - |\mathbf{c}|)/\upsilon + \varepsilon . \qquad (1)$$

The values of Δt_a , Δt_b , Δt_c, are measured by the methods disclosed in EP-A-0 880 712 and the values of **a**, **b**, **c**, and υ are known. Hence the equations (1) can be solved to find the position of the handset, **r**, together with the value of ε .

In WO-A-99/21028, the contents of which are hereby incorporated by reference, it is described how these same time offsets can be measured using locally-created *templates* in a GSM telephone system as follows. Suppose that the handset R has recorded a short burst of the GSM signals from BTS A. Contained within that recording is the framing structure, synchronisation bursts and other 'given' data (or

predetermined values) which are a constant feature of those transmissions. The processor within the handset can create a matching template, based on the known structure of the network signals. Received signals can then be matched by the locally-generated template. When the template finds a match, the correlation peak at the position of best match corresponds to the time offset between the received signals and the local clock inside the handset. For the signals radiated by BTS A this measured time offset, Δt_{a1}, is given by

$$\Delta t_{a1} = (|\mathbf{r} - \mathbf{a}|)/v + \alpha_a + \varepsilon_1 ,$$

where α_a is the time offset of the BTS transmissions and ε_1 is the time offset of the handset's internal clock, both relative to an imaginary universal 'absolute' clock. The signals from BTSs B and C may also be measured in the same way, giving

$$\Delta t_{b1} = (|\mathbf{r} - \mathbf{b}|)/v + \alpha_b + \varepsilon_1,$$

and

$$\Delta t_{c1} = (|\mathbf{r} - \mathbf{c}|)/v + \alpha_c + \varepsilon_1 . \qquad (2)$$

The same measurements can also be made by the LMU, giving

$$\Delta t_{a2} = (|\mathbf{a}|)/v + \alpha_a + \varepsilon_2 ,$$

$$\Delta t_{b2} = (|\mathbf{b}|)/v + \alpha_b + \varepsilon_2 ,$$

and

$$\Delta t_{c2} = (|\mathbf{c}|)/v + \alpha_c + \varepsilon_2 , \qquad (3)$$

where ε_2 is the time offset of the LMU's internal clock relative to the same imaginary universal absolute clock. Subtracting equations 3 from equations 2 gives

$$\Delta t_a = \Delta t_{a1} - \Delta t_{a2} = (|\mathbf{r} - \mathbf{a}| - |\mathbf{a}|)/v + \varepsilon ,$$

$$\Delta t_b = \Delta t_{b1} - \Delta t_{b2} = (|\mathbf{r} - \mathbf{b}| - |\mathbf{b}|)/v + \varepsilon ,$$

and

$$\Delta t_c = \Delta t_{c1} - \Delta t_{c2} = (|\mathbf{r} - \mathbf{c}| - |\mathbf{c}|)/v + \varepsilon , \qquad (4)$$

where $\varepsilon = \varepsilon_1 - \varepsilon_2$. It will be noted that equations 4 are just like equations 1, and can be solved in the same way to find the position of the handset, $\mathbf{r}$, and the value of ε.

It will be apparent that the CURSOR method as described above, in common with all other methods which use the signals from non-synchronised transmitters, requires a network of LMUs to be set up within the coverage area of the telephone system. These units act as reference points at which the unsynchronised signals radiated by the BTSs are measured for comparison with the same signals received by a handset. Each position measurement requires a match to be made between the signals received by the handset from a number of nearby BTSs, and signals received by an LMU from the same set of BTSs. In practice, it is often difficult to find a match using just one LMU, especially if the LMU network is sparse, since the handset may receive signals from BTSs not received by the LMU, and *vice-versa*. It is therefore necessary to combine the measurements from two or more LMUs. However, each new LMU brought into the calculation adds a further unknown clock time offset (ε_2, ε_3 etc.), each of which therefore requires an additional BTS measurement to provide the extra equation needed to solve for all the unknown quantities.

One solution to this problem is presented in WO-A-99/21028 where it is shown how the LMU network can be synchronised. Referring to Figure 2, suppose that an adjacent pair of LMUs, U_1 and U_2, can see a common BTS. The positions of the LMUs and the BTS are all known, so a single measurement of the BTS signals by each LMU is sufficient to determine the clock time offset between the LMUs. For example, suppose that the distance from U_1 to the BTS is s_1, and the distance from U_2 to the BTS is s_2. U_1 measures time offset Δt_1 and U_2 measures Δt_2, given by

$$\Delta t_1 = s_1/v + \alpha + \varepsilon_{21} ,$$

$$\Delta t_2 = s_2/v + \alpha + \varepsilon_{22} , \quad (5)$$

where α is the time offset of the BTS transmissions, and ε_{21} and ε_{22} are the time offsets of the LMU internal clocks in U_1 and U_2 respectively. Subtracting the second equation from the first yields

$$\varepsilon_{21} - \varepsilon_{22} = \Delta t_1 - \Delta t_2 + s_1/v - s_2/v , \quad (6)$$

which is the relative time offset of the clock in U_1 with respect to that in U_2. This process may be repeated for a second pair of LMUs, say U_2 and U_3, and another BTS whose signals can be received by both members of this second pair of LMUs. In this way a synchronisation map may be calculated, which provides the clock offsets of all the LMU internal clocks relative to one of them adopted as a master 'LMU network clock time'. Having established the LMU synchronisation map in this fashion, a CURSOR position measurement can then include any number of LMUs without the penalty of adding an extra unknown time offset for every LMU, since the relative LMU time offsets are known.

The receivers discussed in the preceding paragraphs make measurements of time offsets. More generally, receivers can measure time offsets, phase offsets (which can be converted into time offsets with a modulo 360° ambiguity), frequency offsets or rates of change of frequency offsets. Though these measurements are of different quantities, the present invention is applied usefully to each of them as, when combined with similar measurements made by a second receiver, they can independently provide positional information. Positioning systems making use of these measurements are discussed in a related patent application (our reference MJB06427WO) filed simultaneously herewith.

The present invention teaches how the same advantages of an (effectively) synchronised LMU network may be obtained by setting up one or more 'virtual LMUs' in the network which act as interface nodes for the real LMUs.

According to a first aspect of the invention, there is provided a method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the method comprising

(a) acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) combining the acquired data and calculating the list of offsets relative to the common reference.

In practice the offsets from the list can be used in place of offsets obtained directly from the receiver or receivers.

The relative offsets in time, phase, frequency, or derivatives thereof, with respect to each other or with respect to a reference source, of the signals received by a first receiver from a plurality of the transmission sources may be represented by corresponding offsets or differences in the distances between the transmission sources and the first or second receivers.

The invention also includes apparatus using the method above, the apparatus comprising

(a) means for acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) means for combining the acquired data and calculating the list of offsets relative to the common reference.

In a method using techniques similar to or as described in EP-A-0 880 712, in place of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, data representative of the received signals may be used, from which the offsets of signals received from the transmission sources relative to the reference source may be determined.

Therefore, the invention also includes a method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the method comprising

(a) acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) combining the offsets so determined and calculating the list of offsets relative to the common reference.

The invention also includes apparatus for carrying out the method described immediately above, the apparatus comprising

(a) means for acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) means for determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) means for combining the offsets so determined and calculating the list of offsets relative to the common reference.

A radio positioning method and system including either of the methods and apparatus defined above also form part of the present invention.

The invention also includes apparatus (a 'virtual LMU') for carrying out either or both of these methods. The apparatus may include a computer (located anywhere convenient) and programmed to carry out the required process. Although the following description of a particular application of the invention concerns signals in a digital telephone network, it will be apparent that the invention is by no means restricted to this application but may be applied to any network of one or more transmitters, synchronised or unsynchronised, set up for any purpose.

A virtual LMU includes a computer process which may run on any computer platform able to obtain data from real LMUs. Accordingly, a further aspect of the invention includes a method of calculating and maintaining a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference.

It is assumed that the network of BTSs is *unsynchronised* in that the transmission time offsets of the BTS signals bear no constant or known relationship to each other, but that nevertheless the BTS oscillators are quite *stable*, so that their instantaneous frequencies change only slowly with time. In these circumstances, it is possible to predict the currently received offset in time, phase, frequency, or derivatives thereof of the signals from a given BTS by a given real LMU from sufficiently-recent historical data. The real LMUs in the network make measurements of all the BTSs they can detect in a cyclic fashion, repeating the cycle every few seconds. They maintain these measurements in a stack, replacing the oldest measurements with the most recent. A linear or low-order polynomial fit to the measurements therefore provides a predictor for extrapolation into the near future, or for interpolation in the recent past. Assume that the BTS oscillators are sufficiently stable that reliable predictions can be made over a period of, say, ten minutes. Then, every few minutes, the virtual LMU (VLMU) contacts each real LMU and receives its predictors for the received offsets of the signals from all the BTSs in its measurement set. It is likely that many of the

BTSs will have been measured by more than one LMU, so the VLMU analyses the complete data set from all the real LMUs using well-known methods to determine both (a) the best values of the real LMU internal clock offsets in time, phase, frequency, or derivatives thereof, and hence (b) the received offsets in time, phase, frequency, or derivatives thereof of the signals from all the BTSs which would have been measured by a real LMU located at the assumed position of the VLMU and capable of receiving signals from every BTS.

In the above description of the function of the VLMU, it should be understood that any or all of the LMUs could be replaced by other receivers, not necessarily fixed or at known positions, which have not been set up specifically as LMUs. For example, the data from a number of handsets could be used to determine frequency offsets if the handsets were stationary. Furthermore, it is shown in a related patent application (our reference MJB06427WO) filed simultaneously herewith, how the positions and velocities of handsets can be determined without the need for any LMUs at all.

Particular advantages of using a VLMU in a network include the following:

(a) a full match can be guaranteed between a handset's measurements and a single (virtual) LMU;

(b) the VLMU process minimises the timing errors in individual LMU measurements;

(c) the VLMU list is immediately available to the position calculation process, increasing the speed of computation;

(d) when combined with the ideas described in a related patent application (our reference MJB06427WO) filed simultaneously herewith, a list of receive time offsets can be created in a network of BTSs where there are few if any real LMUs;

(e) the VLMU provides, in effect, a synchronisation map of the real LMU network which network may then be used to monitor the BTS network and, in particular, to determine locations of newly-installed BTSs.

One example of a method and apparatus according to the present invention will now be described with reference to the accompanying drawings, in which:

Figure 1 shows the geometry of a CURSOR system as described in EP-A-0 880 712;

Figure 2 shows adjacent LMUs making measurements of a common BTS;

Figure 3 shows a network of real and virtual LMUs in a system of the invention;

Figure 4 illustrates a similar, simplified network;

Figure 5 shows the positions of LMU sites and BTS sites in a real network;

Figure 6 shows the same network with the addition of a Virtual LMU;

Figure 7 shows the same network with the real LMUs replaced by the Virtual LMU;

Figure 8 illustrates, by way of a flow chart, the processing which takes place inside an LMU;

Figure 9 illustrates, by way of a flow chart, the processing which takes place inside the VLMU;

Figure 10 shows a list of timing offsets generated in a real system such as that shown in the example of Figures 5 to 9; and

Figure 11 shows a table of timing errors associated with LMUs and a virtual LMU in this example.

By way of example, and with reference to Figure 3, the function of a virtual LMU is now described which determines timing offsets.

Consider a network of N real LMUs and M BTSs which includes a virtual LMU (VLMU). The position of the n^{th} LMU, U_n, is represented by the vector $\mathbf{u}_n$ and the position of the m^{th} BTS, B_m, is represented by the vector $\mathbf{b}_m$, both vectors being with respect to the same origin. Signals radiated by BTS m will be received by LMU n after a time lag, and the measurement of this time lag, Δt_{nm}, is given by

$$\Delta t_{nm} = |\mathbf{u}_n - \mathbf{b}_m|/\upsilon + \varepsilon_n + \alpha_m \pm \sigma_{nm}\,, \qquad (7)$$

where ε_n is the clock time offset of LMU n, α_m is the transmission time offset of BTS m, both with respect to an imaginary universal 'absolute' clock, and σ_{nm} is an estimate of the error in the measurement of Δt_{nm}. The assumed position of the virtual LMU, V, is represented by the vector **v**. If the VLMU were able to receive the signals directly from BTS m without error then it would measure a receive time offset, β_m, relative to the imaginary universal absolute clock, given by

$$\beta_m = |\mathbf{v} - \mathbf{b}_m|/\upsilon + \alpha_m. \qquad (8)$$

Substituting for α_m in equation (7) using the value deduced from equation (8) gives

$$\Delta t_{nm} = |\mathbf{u}_n - \mathbf{b}_m|/\upsilon + \varepsilon_n + \beta_m - |\mathbf{v} - \mathbf{b}_m|/\upsilon \pm \sigma_{nm}. \qquad (9)$$

Over the entire network of N LMUs, all of the M BTSs are visible. Each individual LMU, however, will only see a few of them, but as long as there is significant overlap of visibility, it is possible to take the set of all Δt values and solve for values of ε_n and β_m. Hence the VLMU can calculate timings for any BTS as if the network of LMUs were synchronised, or as if just one LMU (the VLMU, V) was all that was needed to cover the entire BTS network.

To illustrate this further, a simplified problem is shown and solved below using $N = 2$ and $M = 4$, i.e. a network consisting of just 2 LMUs monitoring 4 BTSs (see Figure 4). For simplicity it is chosen that $\varepsilon_1 = 0$. This is allowed as the 'absolute' clock time is completely arbitrary and may, for example, be measured by the internal clock of LMU number one. (Note, however, that this choice does introduce an asymmetry into the solution in that the error associated with BTSs three and four are not the same.) The first LMU (U_1) can receive signals from BTS numbers one, two and three, but cannot receive the signals from BTS number four. The second LMU (U_2) can receive the signals from BTSs one, two and four, but cannot see BTS number three. The equations can be written in matrix form as

$$\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \varepsilon_2 \end{pmatrix} = \begin{pmatrix} \Delta t_{11} - \frac{|\mathbf{u}_1 - \mathbf{b}_1| - |\mathbf{v} - \mathbf{b}_1|}{v} \\ \Delta t_{12} - \frac{|\mathbf{u}_1 - \mathbf{b}_2| - |\mathbf{v} - \mathbf{b}_2|}{v} \\ \Delta t_{13} - \frac{|\mathbf{u}_1 - \mathbf{b}_3| - |\mathbf{v} - \mathbf{b}_3|}{v} \\ \Delta t_{21} - \frac{|\mathbf{u}_2 - \mathbf{b}_1| - |\mathbf{v} - \mathbf{b}_1|}{v} \\ \Delta t_{22} - \frac{|\mathbf{u}_2 - \mathbf{b}_2| - |\mathbf{v} - \mathbf{b}_2|}{v} \\ \Delta t_{24} - \frac{|\mathbf{u}_2 - \mathbf{b}_4| - |\mathbf{v} - \mathbf{b}_4|}{v} \end{pmatrix} + \mathbf{Z} \qquad (10)$$

or equivalently as $\mathbf{A}.\mathbf{x} = \mathbf{b} + \mathbf{Z}$, where $\mathbf{Z}$ is an unknown vector of the actual errors on each measurement.

The standard technique known as 'least squares' postulates that the estimate for $\mathbf{x}$ which minimises $\mathbf{Z}$ is given by

$$\mathbf{x} = (\mathbf{A}^T\mathbf{W}\mathbf{A})^{-1}\,\mathbf{A}^T\mathbf{W}\mathbf{b}, \qquad (11)$$

where the symbol $\mathbf{A}^T$ indicates the transpose of the matrix $\mathbf{A}$, and the matrix $\mathbf{W}$ is defined by

$$\mathbf{W} = \begin{pmatrix} \frac{1}{\sigma_{11}^2} & 0 & 0 & 0 & 0 & 0 \\ 0 & \frac{1}{\sigma_{12}^2} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{\sigma_{13}^2} & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{\sigma_{21}^2} & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{\sigma_{22}^2} & 0 \\ 0 & 0 & 0 & 0 & 0 & \frac{1}{\sigma_{24}^2} \end{pmatrix} \qquad (12)$$

This particular example can be solved explicitly. For simplicity, it is assumed that all the values of σ_{nm} are the same, and equal to σ. This gives the result

$$\beta_1 = (3D_{11} + D_{12} + D_{21} - D_{22})/4 \qquad \pm 0.87\sigma,$$
$$\beta_2 = (3D_{12} + D_{11} + D_{22} - D_{21})/4 \qquad \pm 0.87\sigma,$$

$$\begin{aligned} \beta_3 &= D_{13} && \pm 1.00\sigma, \\ \beta_4 &= (\,2D_{24} + D_{11} + D_{12} - D_{21} - D_{22}\,)/2 && \pm 1.41\sigma, \\ \varepsilon_2 &= (D_{21} + D_{22} - D_{11} - D_{12})/2 && \pm 1.00\sigma, \end{aligned} \tag{13}$$

where

$$D_{nm} = \Delta t_{nm} - \frac{|\mathbf{u}_n - \mathbf{b}_m| - |\mathbf{v} - \mathbf{b}_m|}{v}. \tag{14}$$

Note that even in this simple case, when a BTS is seen by both LMUs, the errors in the calculated offsets are less than those in each of the measurements themselves. This is an important advantage of the virtual LMU method.

The LMUs may also contain other means of synchronisation. For example, each real LMU could be connected to a GPS or other timing reference receiver, G, which serves to provide the common timing reference. In this case, the LMU network may be considered as synchronised already to this common timing reference (say GPS standard time), and then the VLMU need not solve for the individual values of ε as these are already known. One advantage of using other means of synchronisation is that there is no longer a requirement for overlap of visibility of BTSs between adjacent LMUs. If each BTS site also carried an LMU, then that LMU would need only to be able to receive the (very strong) signals from its co-sited BTS transmitter(s), thereby simplifying the installation of the LMU antenna.

The VLMU mode of operation described above may be called the 'pull mode' as it requires the VLMU to instigate data transfer to itself from every real LMU. It is also possible to have each real LMU continuously check the difference between its own prediction of the receive time offset from every BTS using the values calculated from the set of predictors last sent to the VLMU and the actual measured values. When any one of these differences exceeds a given value, the LMU can send its new predictor set to the VLMU. This mode of operation may be called the 'push mode'. The particular mode appropriate for a real system depends, amongst other things, on the stability of the BTS network.

An example of a prototype system constructed in accordance with the invention will now be described, in which timing measurements made by a number of LMUs are combined to create a list of receive time offsets for all the GSM BTSs in and around Cambridge, UK, as if they were observed by a single "Virtual" LMU.

The positions of nine LMUs, $U_1 - U_9$ (shown as filled circles) and twenty three Cambridge area BTSs, $B_1 - B_{23}$ (shown by unfilled squares) are plotted in Figure 5 on an Ordinance Survey (OS) grid. Each LMU comprises (a) hardware including an internal clock, a GSM radio, a computer, and a telephone connection, and (b) software including a program to compile a list of receive time offsets.

Figure 8 illustrates, by way of a flow chart, the main elements of the LMU software residing in each LMU, $U_1 - U_9$. Every few seconds the "scan cycle" program is entered at step A1. The program proceeds, in steps A2, A3, A6 and A7, to tune the GSM radio to each GSM transmission channel in turn and scan for BCCH signals. In the event that a BCCH signal is detected in step A3, the program calculates the receive time offset of the signal relative to its internal clock (in step A4) and updates its list of time offsets accordingly in step A5. The BCCH is also decoded to produce the ID of the BTS B_n from which the signal is received. Figure 5 also shows lines between LMUs and the BTSs detected by them as a result of the scan cycle routine.

Figure 6 shows the positions of the nine LMUs, the twenty three BTSs monitored by those LMUs and a Virtual LMU V (plotted as an unfilled circle). The Virtual LMU V comprises (a) hardware including a telephone connection to each real LMU and a computer, and (b) software including a program to compile a list of "virtual" receive time offsets.

Figure 9 illustrates, by way of a flow chart, the main elements of the VLMU software. Every 4 minutes the "VLMU update" program is entered at step V1. The program proceeds, in steps V2, V3, V5 and V6, to connect to each of the real LMUs via the telephone connections. If the connection to a given LMU $U_1 - U_9$ succeeds, the program, in step V4, extracts that LMU's list of receive time offsets. On completion of the connection cycle, the program (in step V7) combines the data to produce a list of receive time offsets for all the BTSs monitored by the LMU network. An example

of this list is shown in Figure 10 where part of a table of receive time offsets generated by the VLMU is reproduced. The first column shows the BTS identifier and the figures in the table are in units of 1.85 microseconds. Figure 6 also shows lines between the VLMU V and each real LMU $U_1 - U_9$ from which the VLMU software is able to extract a list of time offsets.

Once the "VLMU update" has been completed, the combined list of timings generated is equivalent to that which would have been observed had there been a single (real) LMU at the VLMU's location making timing measurements of every BTS in the network. Figure 7 illustrates this equivalence by showing the virtual monitoring of each BTS's timing measurements by the Virtual LMU (shown as lines between the VLMU V and the BTSs $B_1 - B_{23}$).

Each timing measurement has an associated error which, in most cases, is smaller than the errors in the timing measurements made by the individual real LMUs. This is illustrated in the table of Figure 11, which shows part of the list produced by the VLMU during operation. The first column shows the identifier of each BTS. The columns headed 1 to 9 each relate to a particular one of the nine real LMUs.. The figures in the table are errors in the timing measurements made by the real LMUs of the signals from the corresponding BTSs. An empty cell indicates that the LMU is unable to receive a BTS's signal. The column headed VLMU shows the result of combining the measurements using the method outlined above.

The timings in the table of Figure 11 are in units of 1.85 microseconds. Note that the VLMU timing errors are generally smaller than those estimated for real LMU timings, confirming an advantage of the VLMU method in reducing errors.

CLAIMS

1. A method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the method comprising

(a) acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) combining the acquired data and calculating the list of offsets relative to the common reference.

2. A method of generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the method comprising

(a) acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) combining the offsets so determined and calculating the list of offsets relative to the common reference.

3. A radio positioning method for determining the position of one or more receivers the positions of which are unknown, which method includes the method of claim 1 or claim 2.

4. A radio positioning method according to claim 3, wherein the common reference comprises an external reference.

5. A radio positioning method according to claim 4, wherein the common reference comprises a GPS signal.

6. A radio positioning method according to any of claims 3 to 5, wherein the step of acquiring data from said one or more receivers includes instigating acquisition of said data from a common location.

7. A radio positioning method according to any of claims 3 to 5, wherein the step of acquiring data from said one or more receivers includes instigating acquisition of said data from each said receiver at times determined by each said receiver.

8. Apparatus for generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the apparatus comprising

(a) means for acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver comprising offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source in each receiver or to each other; and

(b) means for combining the acquired data and calculating the list of offsets relative to the common reference.

9. Apparatus for generating a list of offsets in time, phase, frequency, or derivatives thereof, or their equivalents expressed as offsets in distance or derivatives thereof, of a plurality of transmission source signals, received at a given location, relative to a common reference, the apparatus comprising

(a) means for acquiring data from one or more receivers, the positions of which may be known or determined, the data from a receiver being representative of the received signals;

(b) means for determining from the acquired data the offsets in time, phase, frequency, or derivatives thereof, respectively of signals received from the transmission sources relative to a reference source or to each other; and

(c) means for combining the offsets so determined and calculating the list of offsets relative to the common reference.

10. A radio positioning system including apparatus according to claim 8 or to claim 9.

11. A radio positioning system according to claim 10, wherein the common reference comprises a reference external to said receivers.

12. A radio positioning system according to claim 11, wherein the common reference comprises a GPS signal.

13. A radio positioning system according to any of claims 10 to 12, wherein the means for acquiring data from said one or more receivers includes a computer system arranged to instigate the transfer of said data from said one or more receivers to said computer system at times determined by said computer system.

14. A radio positioning system according to any of claims 10 to 13, wherein the means for acquiring data from said one or more receivers includes a computer system, and including means for instigating said acquisition of data from each said receiver at times determined by each said receiver.

15. A digital telephone network, including a radio positioning system according to any of claims 10 to 14.

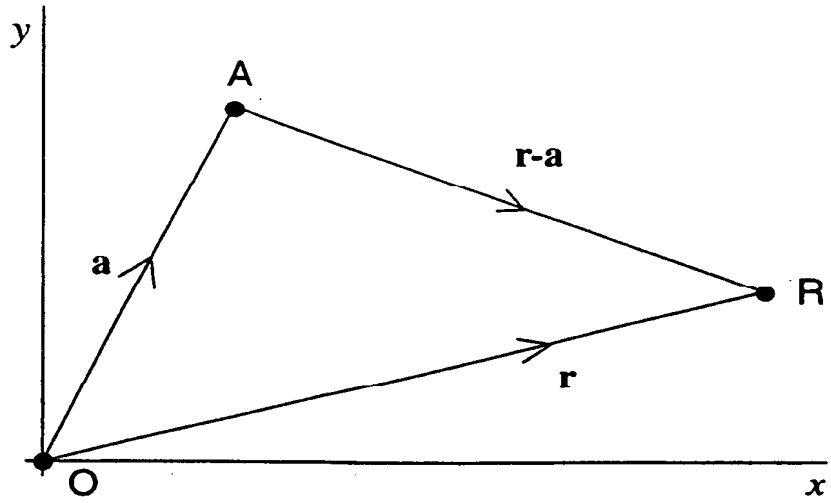


Figure 1

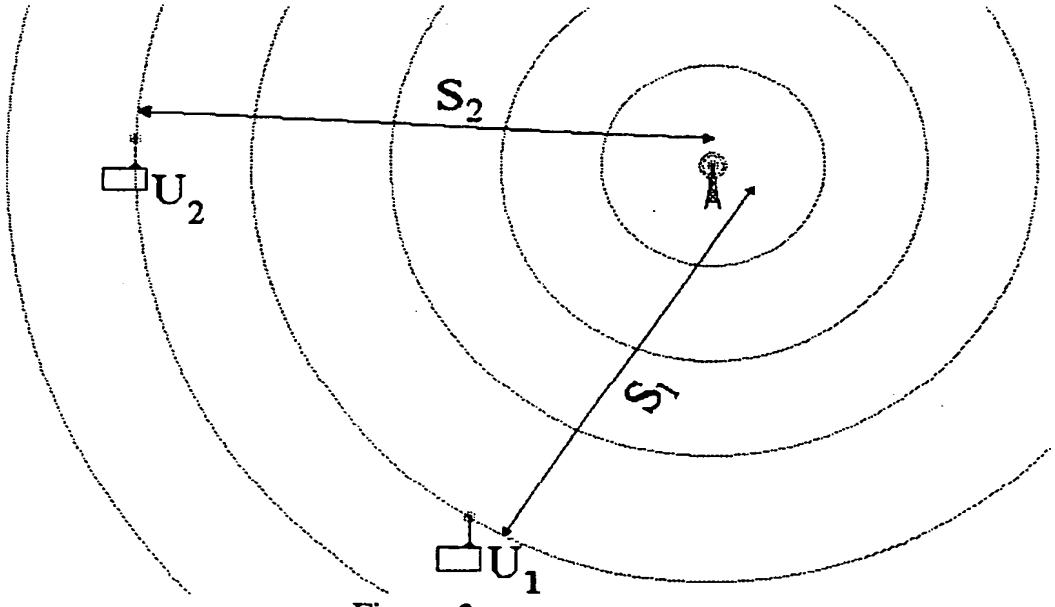


Figure 2

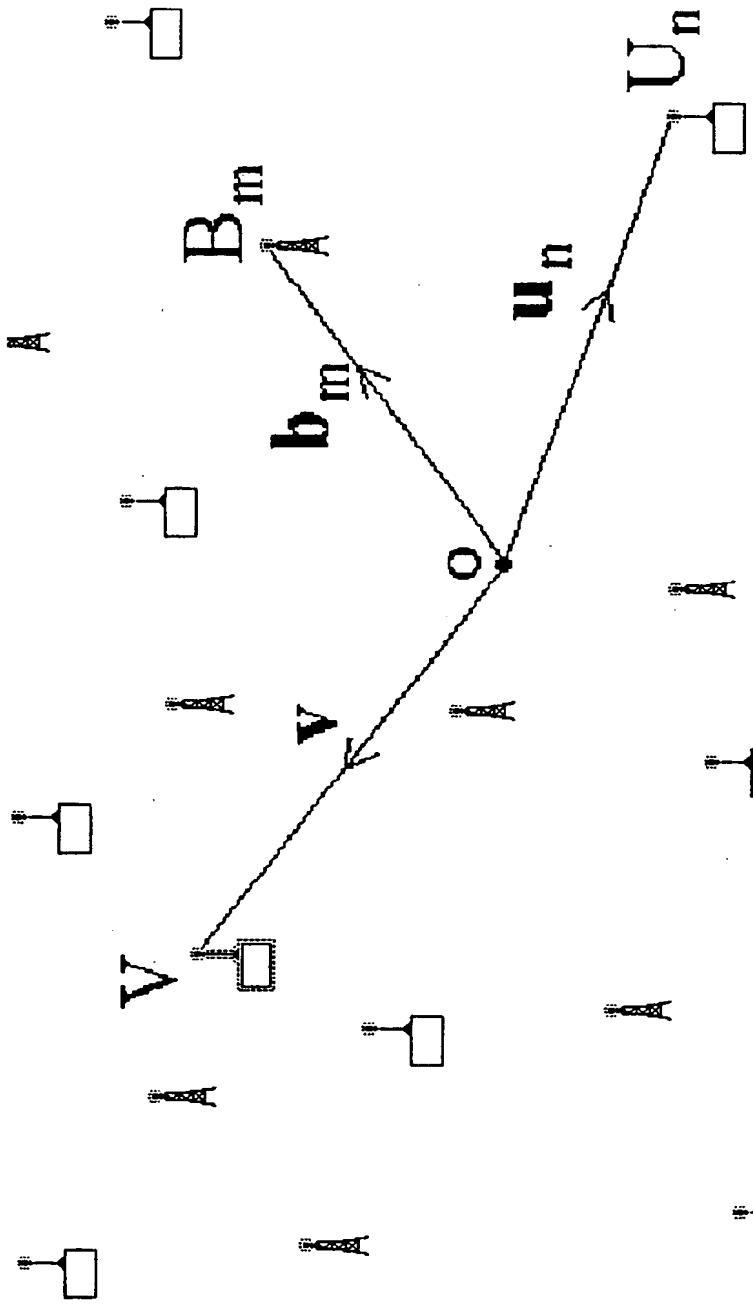


Figure 3

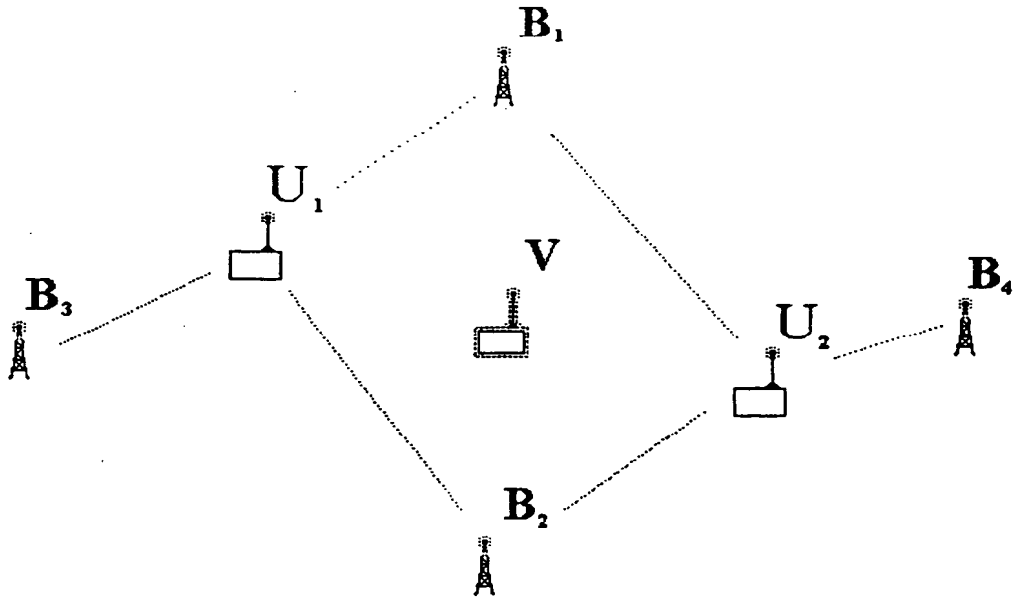


Figure 4

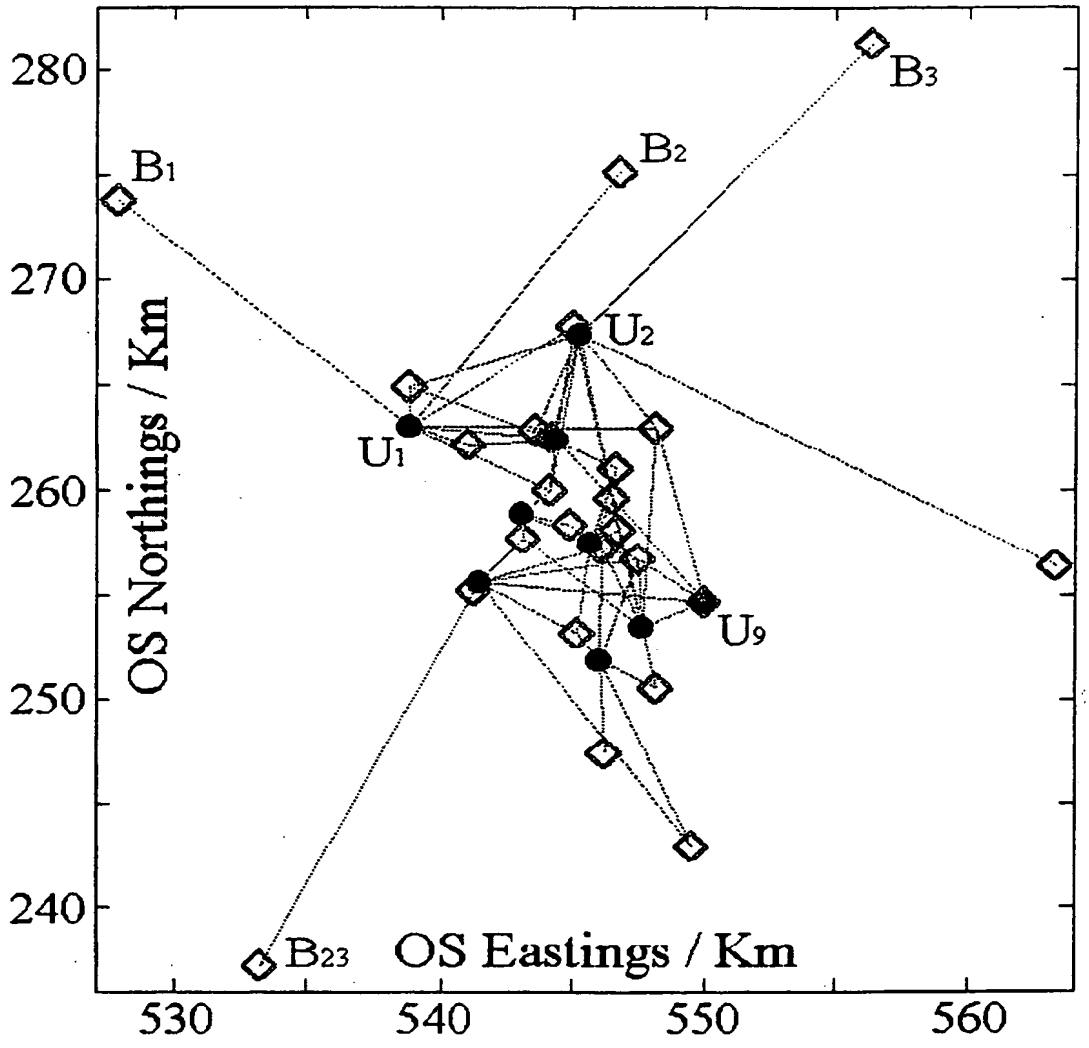

280
270
260
250
240
530
540
550
560
OS Northings / Km
OS Eastings / Km
B1
B2
B3
B23
U1
U2
U9

Figure 5

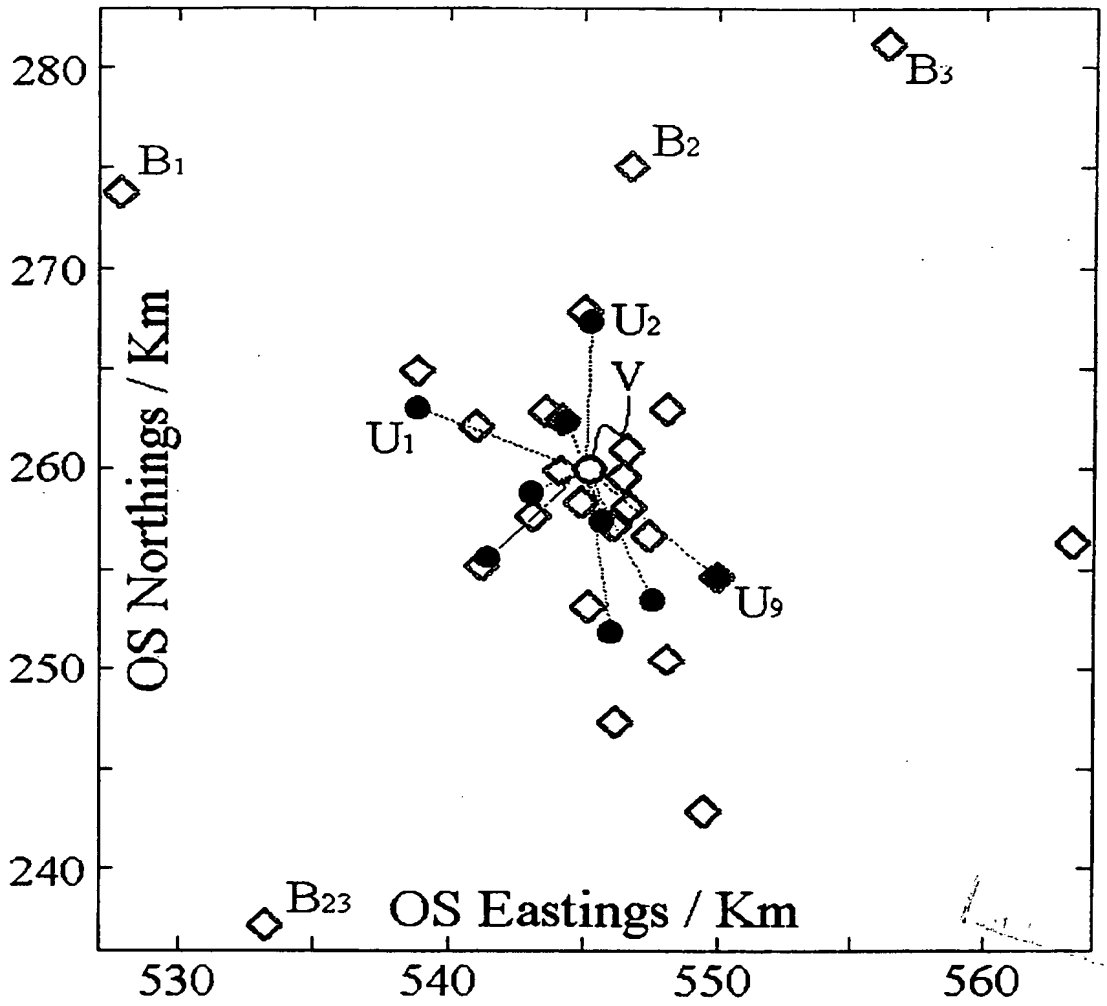

280
270
260
250
240
530
540
550
560
OS Northings / Km
OS Eastings / Km
B1
B2
B3
B23
U1
U2
U9
V

Figure 6

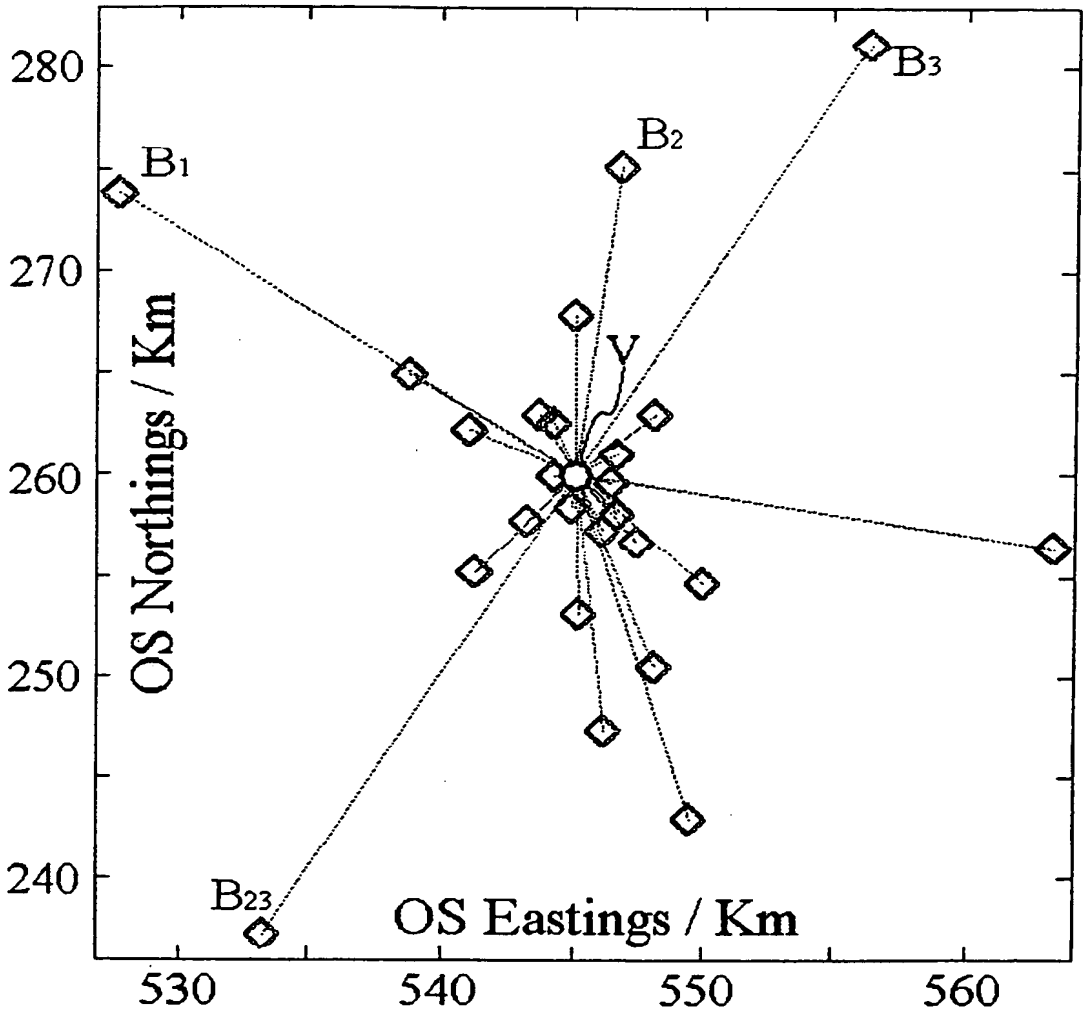

280
270
260
250
240
530
540
550
560
OS Northings / Km
OS Eastings / Km
B1
B2
B3
B23
V

Figure 7

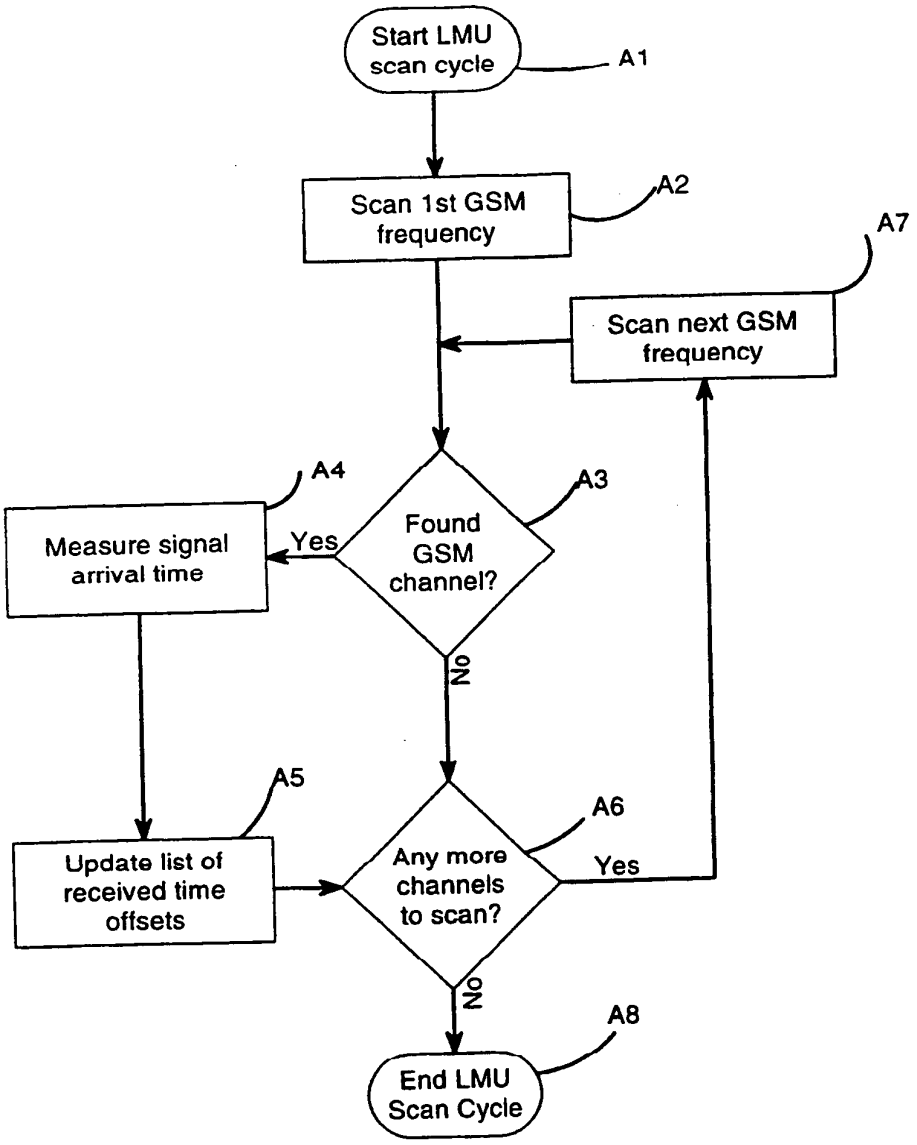

Start LMU scan cycle
A1
Scan 1st GSM frequency
A2
A7
Scan next GSM frequency
A4
A3
Measure signal arrival time
Yes
Found GSM channel?
No
A5
A6
Update list of received time offsets
Any more channels to scan?
Yes
No
A8
End LMU Scan Cycle

Figure 8

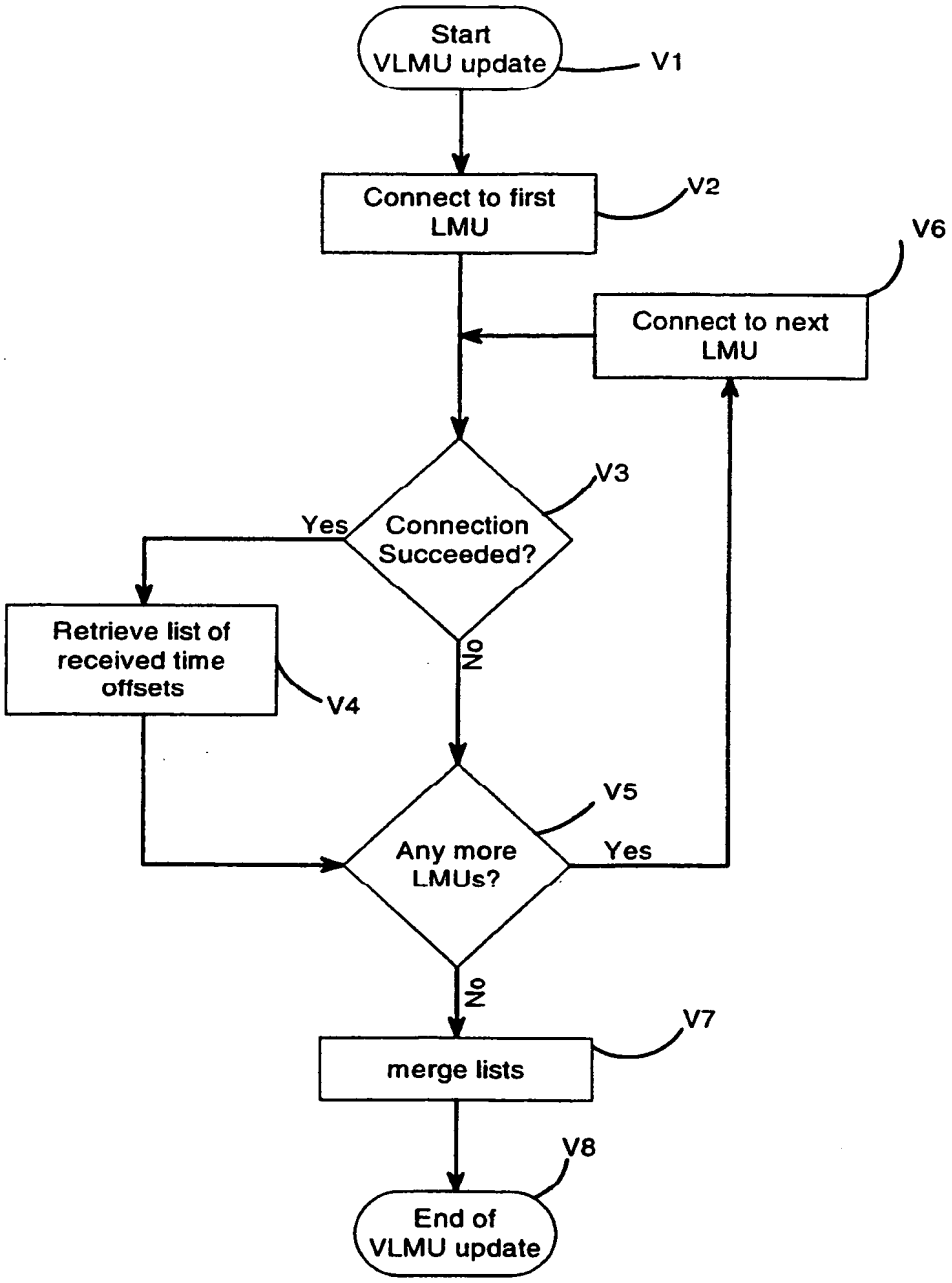

Start VLMU update
V1
Connect to first LMU
V2
V6
Connect to next LMU
V3
Yes
Connection Succeeded?
Retrieve list of received time offsets
V4
No
V5
Any more LMUs?
Yes
No
V7
merge lists
V8
End of VLMU update

Figure 9

BTS identifier	VLMU receive time offsets
1727	1959.950
1728	75.364
[illegible]	[illegible]
[illegible]	[illegible]
129[illegible]	[illegible]479
17332	[illegible]97.851
17333	797.813
17342	2072.920
17343	182.409
18072	1686.043
18073	1028.109
33060	1061.910
33070	1453.715
42140	1343.821
55440	60.012
55500	2026.607
55512	1690.698
55513	1772.834
[illegible]30	2221[illegible]

Figure 10

LMU number / BTS identifier	1	2	3	4	5	6	7	8	9	VLMU
1727					0.098	0.168				0.101
1728	0.091				0.136	0.076		0.071		0.048
[illegible]				0.159						0.099
[illegible]								0.087		[illegible]
12[illegible]		[illegible]54			0.092					[illegible]01
17332										0.083
17333		0.163	0.061						[illegible]64	0.055
17342	0.087			[illegible]		0.074	0.049	[illegible]		0.031
17343				0.044			0.047			0.041
18072		0.048	0.086						0.089	0.050
18073		0.125								0.129
33060			0.045	0.047			0.036			0.033
33070		0.050	0.033						0.138	0.040
42140		0.053	0.084			0.171			0.055	0.045
55440	0.056									0.069
55500			0.058	0.066	0.138	0.046	0.067			0.033
55512				0.048		0.038	0.039			0.032
55513				0.047			0.050		0.078	0.040
[illegible]									0.096	0.1[illegible]
[illegible]					0.146					
[illegible]									[illegible]	

Figure 11

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 00/02104

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S5/10 G01S5/00 G01S1/02 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 689 270 A (GREENBAUM LOUIS A ET AL) 18 November 1997 (1997-11-18)	1,8
Y	abstract	2-6, 9-13,15
A	column 2, line 5 -column 3, line 32 column 5, line 60 -column 6, line 16 column 15, line 37 -column 16, line 57 column 17, line 9 -column 18, line 8 column 19, line 12 -column 20, line 17 figure 1	7,14

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2000	12/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Roost, J

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 00/02104

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 11384 A (CAMBRIDGE POSITIONING SYS LTD ;GRAINGE KEITH J B (GB); DUFFETTT SM) 27 March 1997 (1997-03-27) cited in the application	2-6, 9-13,15
A	abstract page 2, line 28 -page 3, line 31 page 4, line 21 -page 5, line 14 page 17, line 20 -page 18, line 4	1,8
X	WO 98 52376 A (NOKIA TELECOMMUNICATIONS OY ;RANTALAINEN TIMO (FI); SILVENTOINEN M) 19 November 1998 (1998-11-19)	1,8
A	abstract page 1, line 23 - line 34 page 4, line 16 -page 6, line 11 page 7, line 24 -page 10, line 17 page 11, line 35 -page 12, line 13 page 13, line 1 - line 12	2-4,6,7, 9-11, 13-15
A	WO 97 23785 A (DRANE CHRISTOPHER R ;MACNAUGHTAN MALCOLM D (AU); SCOTT CRAIG A (AU) 3 July 1997 (1997-07-03)	1,2,8,9
	abstract page 6, line 12 - line 15 page 10, line 4 -page 14, line 14	
A	WO 97 30360 A (ERICSSON TELEFON AB L M) 21 August 1997 (1997-08-21)	1,2,8,9
	abstract page 6, line 17 -page 7, line 5 page 11, line 23 -page 14, line 31	
A	WO 99 21028 A (CAMBRIDGE POSITIONING SYS LTD ;DUFFETT SMITH PETER (GB); HANSEN PA) 29 April 1999 (1999-04-29) cited in the application	1,2
	abstract page 1, line 18 -page 2, line 7 page 8, line 15 - line 28 page 10, line 12 -page 12, line 15	
A	EP 0 303 371 A (DUFFETT SMITH PETER JAMES) 15 February 1989 (1989-02-15) cited in the application	2
	abstract	

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte onal Application No
PCT/GB 00/02104

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5689270 A	18-11-1997	US 5499032 A	12-03-1996
		US 5280295 A	18-01-1994
		US 5173710 A	22-12-1992
		CA 2179169 A	22-06-1995
		AU 665571 B	11-01-1996
		AU 2540292 A	16-03-1993
		CA 2114648 A	04-03-1993
		EP 0598844 A	01-06-1994
		JP 6510120 T	10-11-1994
		WO 9304378 A	04-03-1993
WO 9711384 A	27-03-1997	AU 713289 B	25-11-1999
		AU 6994296 A	09-04-1997
		BR 9610493 A	06-04-1999
		CA 2230982 A	27-03-1997
		CN 1202968 A	23-12-1998
		EP 0880712 A	02-12-1998
		JP 11513482 T	16-11-1999
		RU 2137150 C	10-09-1999
		US 6094168 A	25-07-2000
WO 9852376 A	19-11-1998	AU 2895997 A	08-12-1998
		EP 1008269 A	14-06-2000
		NO 995452 A	08-11-1999
WO 9723785 A	03-07-1997	AU 708505 B	05-08-1999
		AU 1133297 A	17-07-1997
WO 9730360 A	21-08-1997	SE 513196 C	31-07-2000
		AU 1817497 A	02-09-1997
		CA 2245878 A	21-08-1997
		CN 1211377 A	17-03-1999
		EP 0883968 A	16-12-1998
		JP 2000504838 T	18-04-2000
		SE 9600577 A	17-08-1997
		US 5960355 A	28-09-1999
WO 9921028 A	29-04-1999	AU 9549898 A	10-05-1999
		EP 1025453 A	09-08-2000
		NO 20002068 A	19-04-2000
EP 0303371 A	15-02-1989	AT 86757 T	15-03-1993
		AU 2120788 A	09-03-1989
		BR 8807655 A	05-06-1990
		CA 1314964 A	23-03-1993
		DE 3879032 A	15-04-1993
		DE 3879032 T	24-06-1993
		DK 34690 A	09-02-1990
		EP 0377592 A	18-07-1990
		ES 2038758 T	01-08-1993
		WO 8901637 A	23-02-1989
		HK 38994 A	29-04-1994
		JP 2504673 T	27-12-1990
		NO 177944 B	11-09-1995
		US 5045861 A	03-09-1991

TENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
MJB06733WO		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/GB 00/02104	01/06/2000	01/06/1999
Applicant		
CAMBRIDGE POSITIONING SYSTEMS Ltd		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.

[ ] the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :

[ ] contained in the international application in written form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readble form.

[ ] the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. [ ] **Certain claims were found unsearchable** (See Box I).

3. [ ] **Unity of invention is lacking** (see Box II).

4. With regard to the **title,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

[X] the text is approved as submitted by the applicant.

[ ] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 4

[X] as suggested by the applicant.

[ ] because the applicant failed to suggest a figure.

[ ] because this figure better characterizes the invention.

[ ] None of the figures.

INTERNATIONAL SEARCH REPORT

[redacted]

International Application No
[redacted]B 00/02104

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01S5/10 G01S5/00 G01S1/02 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01S H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 689 270 A (GREENBAUM LOUIS A ET AL) 18 November 1997 (1997-11-18)	1,8
Y	abstract	2-6, 9-13,15
A	column 2, line 5 -column 3, line 32 column 5, line 60 -column 6, line 16 column 15, line 37 -column 16, line 57 column 17, line 9 -column 18, line 8 column 19, line 12 -column 20, line 17 figure 1	7,14

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
5 September 2000	12/09/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Roost, J

2

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

[redacted]

International Application No
[redacted]B 00/02104

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 97 11384 A (CAMBRIDGE POSITIONING SYS LTD ;GRAINGE KEITH J B (GB); DUFFETTT SM) 27 March 1997 (1997-03-27) cited in the application	2-6, 9-13,15
A	abstract page 2, line 28 -page 3, line 31 page 4, line 21 -page 5, line 14 page 17, line 20 -page 18, line 4	1,8
X	WO 98 52376 A (NOKIA TELECOMMUNICATIONS OY ;RANTALAINEN TIMO (FI); SILVENTOINEN M) 19 November 1998 (1998-11-19)	1,8
A	abstract page 1, line 23 - line 34 page 4, line 16 -page 6, line 11 page 7, line 24 -page 10, line 17 page 11, line 35 -page 12, line 13 page 13, line 1 - line 12	2-4,6,7, 9-11, 13-15
A	WO 97 23785 A (DRANE CHRISTOPHER R ;MACNAUGHTAN MALCOLM D (AU); SCOTT CRAIG A (AU) 3 July 1997 (1997-07-03) abstract page 6, line 12 - line 15 page 10, line 4 -page 14, line 14	1,2,8,9
A	WO 97 30360 A (ERICSSON TELEFON AB L M) 21 August 1997 (1997-08-21) abstract page 6, line 17 -page 7, line 5 page 11, line 23 -page 14, line 31	1,2,8,9
A	WO 99 21028 A (CAMBRIDGE POSITIONING SYS LTD ;DUFFETT SMITH PETER (GB); HANSEN PA) 29 April 1999 (1999-04-29) cited in the application abstract page 1, line 18 -page 2, line 7 page 8, line 15 - line 28 page 10, line 12 -page 12, line 15	1,2
A	EP 0 303 371 A (DUFFETT SMITH PETER JAMES) 15 February 1989 (1989-02-15) cited in the application abstract	2

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
[redacted]B 00/02104

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5689270 A	18-11-1997	US 5499032 A	12-03-1996
		US 5280295 A	18-01-1994
		US 5173710 A	22-12-1992
		CA 2179169 A	22-06-1995
		AU 665571 B	11-01-1996
		AU 2540292 A	16-03-1993
		CA 2114648 A	04-03-1993
		EP 0598844 A	01-06-1994
		JP 6510120 T	10-11-1994
		WO 9304378 A	04-03-1993
WO 9711384 A	27-03-1997	AU 713289 B	25-11-1999
		AU 6994296 A	09-04-1997
		BR 9610493 A	06-04-1999
		CA 2230982 A	27-03-1997
		CN 1202968 A	23-12-1998
		EP 0880712 A	02-12-1998
		JP 11513482 T	16-11-1999
		RU 2137150 C	10-09-1999
		US 6094168 A	25-07-2000
WO 9852376 A	19-11-1998	AU 2895997 A	08-12-1998
		EP 1008269 A	14-06-2000
		NO 995452 A	08-11-1999
WO 9723785 A	03-07-1997	AU 708505 B	05-08-1999
		AU 1133297 A	17-07-1997
WO 9730360 A	21-08-1997	SE 513196 C	31-07-2000
		AU 1817497 A	02-09-1997
		CA 2245878 A	21-08-1997
		CN 1211377 A	17-03-1999
		EP 0883968 A	16-12-1998
		JP 2000504838 T	18-04-2000
		SE 9600577 A	17-08-1997
		US 5960355 A	28-09-1999
WO 9921028 A	29-04-1999	AU 9549898 A	10-05-1999
		EP 1025453 A	09-08-2000
		NO 20002068 A	19-04-2000
EP 0303371 A	15-02-1989	AT 86757 T	15-03-1993
		AU 2120788 A	09-03-1989
		BR 8807655 A	05-06-1990
		CA 1314964 A	23-03-1993
		DE 3879032 A	15-04-1993
		DE 3879032 T	24-06-1993
		DK 34690 A	09-02-1990
		EP 0377592 A	18-07-1990
		ES 2038758 T	01-08-1993
		WO 8901637 A	23-02-1989
		HK 38994 A	29-04-1994
		JP 2504673 T	27-12-1990
		NO 177944 B	11-09-1995
		US 5045861 A	03-09-1991